Draft Vision 2.0 Modeling System

Limited Scope Release

General Model Documentation

Addendum to ARB's 2015 Mobile Source Strategy Document

October 9, 2015

Vision 2.0 Modeling System

ARB's Vision for Clean Air Framework[1], released in 2012, was developed to enhance ARB's ability to conduct transportation system-wide, multi-pollutant analysis to inform policy development. Initially based on the Argonne National Laboratory (ANL) national VISION model which only estimated on-road vehicle greenhouse gas (GHG) emissions using national average emission factors, ARB's Vision 1.0 model included California-specific data and methodologies and expanded the ability of the model to estimate upstream and tailpipe emissions of both GHG and criteria pollutants from the operation of light - and heavy- duty vehicles in California.

ARB staff continued building on the Vision 1.0 model framework, to develop the present Vision 2.0 model, an updated and expanded emission estimation tool that can analyze multiple potential technology and fuel pathways for individual emission sources while collectively considering multiple sectors, fuels, and technologies in comprehensive scenarios to study different pathways to meeting California's air quality and climate goals. A detailed overview of the Vision 2.0 model was presented at a public workshop[2] in March 2015.

Vision 2.0 model is designed with a primary focus on mobile source sectors, but also seamlessly integrates other economic sectors including energy and fuel production, other non-energy sources, and energy use in buildings. The model uses ARB's most recent official inventory data including EMFAC2014[3], and also considers all adopted transportation, fuels, and related policies.

This technical documentation provides a draft discussion of the Vision 2.0 modeling tool, with specific focus on the use of model in analyzing the mobile source strategies as discussed in ARB's recently released Mobile Source Strategy (henceforth Strategy) draft discussion document[4]. Note that this public release of the Vision 2.0 model is limited in scope to complement the mobile source sectors and the two scenarios assessed in the Strategy document. ARB staff intends to release a full version of Vision 2.0 model in early 2016, along with a detailed user's guide and technical model documentation.

The current release of the Vision 2.0 modeling system includes a suite of six model components: (1) a passenger Vehicle module; (2) a heavy duty vehicle module; (3) an off-road module for forklifts and airport ground support equipment; (4) a locomotives module; (5) an ocean going vessels module; and (6) an energy module. To illustrate the capabilities of Vision 2.0 model and level of detail that lies in the model design, the on-road vehicle modules are discussed in greater detail here in the context of the two scenarios in the Strategy document – (1) "State Implementation Plan (SIP) Measure Concepts"; and (2) "Cleaner Technologies and Fuels". The other modules will be discussed in greater detail in the full release documentation of the Vision 2.0 model in

[1] Vision Models, http://www.arb.ca.gov/planning/vision/vision.htm
[2] Vision 2.0 Workshop, http://www.arb.ca.gov/planning/vision/workshops.htm
[3] Mobile Source Emissions Inventory http://www.arb.ca.gov/msei/categories.htm
[4] Mobile Source Strategy Discussion Draft, http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.htm

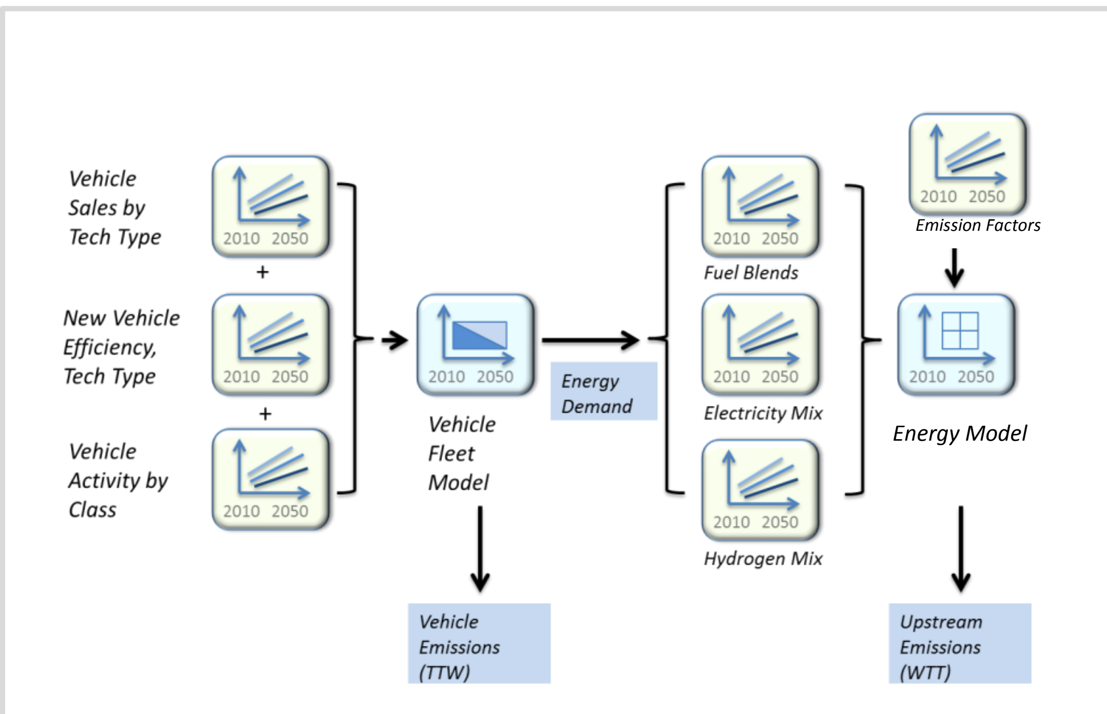
2016. Also, note that the current release of the Vision model does not explicitly feature a user-friendly interface to seamlessly provide ability to change default data; the full release of the model in 2016 is envisioned to provide user-control of many primary variables within the model for improved scenario analysis capacity.

Vision modeling tools and related documentation are available at http://www.arb.ca.gov/planning/vision/vision.htm. ARB's draft Mobile Source Strategy discussion document which includes Vision 2.0 scenario assessments and general overview of Vision 2.0 methodology is available at http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.htm.

Vision 2.0 Model – General Methodology

The Vision modeling system incorporates detailed data from ARB's official mobile source inventories (including EMFAC2014, locomotives, ships, and OFFROAD) into separate "vehicle fleet modules" where comprehensive scenarios can be run for individual mobile source sectors. The tank-to-wheel (TTW) energy demand and tailpipe emission outputs from the individual "vehicle fleet modules" are aggregated into a central "energy module" where input assumptions on fuel mix and supply are considered to estimate the well-to-tank fuel production related emissions. Figure 1 shows the general framework of the Vision 2.0 model. For example, information about changing technology sales, how clean those technologies are, and any changes in the transportation system efficiency are input to specific "vehicle fleet modules". The model evaluates the impact of the assumptions on the TTW emissions and the associated energy demand. This energy demand from the "vehicle fleet modules" is input to the energy module along with assumptions about the mix of fuels to estimate upstream WTT emissions. Combining the WTT and TTW outputs from the model provides the full well-to-wheel impacts of the scenario assumptions on the energy needs and associated emissions.

Figure 1: Framework of Vision 2.0 Model



Vision 2.0: On-road Vehicle Fleet Modules

The Vision 2.0 passenger vehicle module (PVM) and heavy duty vehicle (HDV) module forecast vehicle population, sales, fuel efficiency, turnover, vehicle-miles traveled (VMT), energy demand, and pollutant emissions of nitrogen oxides (NOx), particulate matter less than 2.5 microns ($PM_{2.5}$), and reactive organic gases (ROG) of various vehicle types in California under several SIP and greenhouse gas (GHG) compliance strategies. All scenario analyses are provided out to calendar year 2050 for the vehicle categories found in ARB's official on-road mobile source inventory model, EMFAC2014.

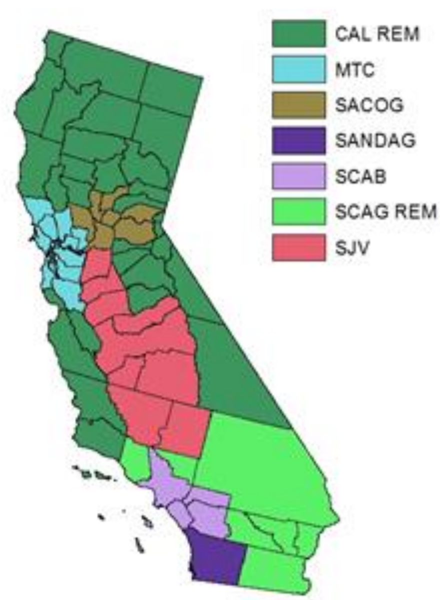
In general, the on-road vehicle fleet modules are best described as a tool that uses official EMFAC2014 data as a baseline, then allows the user to control population, VMT, efficiency or emissions factors to simulate a control strategy (or dozens of control strategies simultaneously). The user also has wide control over technology introduction and penetration. For this initial model release, user control capabilities are not readily provided in a user-friendly interface, but are accessible within the model code for the users with enhanced software coding abilities.

The PVM and HDV module outputs are aggregated to seven geographic areas of California as shown in Figure 2. These regions are aggregations of the 69 geographic regions in the EMFAC2014 model, which are uniquely identified by the county, air basin, and air district (COABDIS) specific to that region, and allows for analyzing areas where similar strategies and technologies can be applied based on the fleet composition and vehicle behavior specific to the areas. Splitting these aggregated regions back to 69-COABDIS regions is possible within the modules, but in general is not included in the output choices at this time.

- *South Coast Air Basin (SCAB):* those counties and geographic areas defined by California law as the South Coast Air Basin. Includes non-attainment areas for the 1997 and 2008 ozone air quality standards as well as the 1997 and 2006 particulate matter less than 2.5 microns ($PM_{2.5}$) air quality standards.

- *Southern California Association of Governments (SCAG REM):* those remaining counties and geographic areas under the jurisdiction of the Southern California Association of Governments not included in the SCAB. Includes non-attainment areas for the 1997 and 2008 ozone air quality standards as well as the 1997

Figure 1: Vision Geographic Areas



and 2006 $PM_{2.5}$ air quality standards.

- *San Diego Association of Governments (SANDAG):* the geographic area confined by San Diego County. Includes non-attainment areas for the 1997 and 2008 ozone air quality standards.
- *San Joaquin Valley (SJV):* those counties and geographic areas defined by California law as the San Joaquin Valley Air Basin plus the eastern portion of Kern County not included in the San Joaquin Valley Air Basin. Includes non-attainment areas for the 1997 and 2008 ozone air quality standards as well as the 1997 and 2006 $PM_{2.5}$ air quality standards.
- *Sacramento Area Council of Governments (SACOG):* those counties and geographic areas under the jurisdiction of the Sacramento Council of Governments. Includes non-attainment areas for the 1997 and 2008 ozone air quality standards as well as the 2006 $PM_{2.5}$ air quality standards.
- *Metropolitan Transportation Commission (MTC):* those counties and geographic areas under the jurisdiction of the Metropolitan Transportation Commission. Includes non-attainment areas for the 1997 and 2008 ozone air quality standards as well as the 2006 $PM_{2.5}$ air quality standards.
- *California Remaining Areas (CAL REM):* All remaining counties in California not in one the regions defined above. Some of the counties within this area are non-attainment for the ozone and/or $PM_{2.5}$ air quality standards.

PASSENGER VEHICLE MODULE (PVM)

The Passenger Vehicle Module provides outputs for the following vehicle categories found in ARB's official EMFAC2014 model.

EMFAC Vehicle ID	Description
LDA	Light-Duty Automobiles (i.e. Passenger Cars)
LDT1	Light-Duty Trucks (0-3,750 lbs GVWR)
LDT2	Light-Duty Trucks (3,751-5,750 lbs GVWR)
MDV	Medium-Duty Trucks (5,751-8,500 lbs GVWR)
UBUS	Urban Buses
SBUS	School Buses
OBUS	Other Buses

The vehicle types listed above are further split into the following technology categories:

Technology ID	Description
GAS	Gasoline Fueled Vehicles
DSL	Diesel Fueled Vehicles
ELE	Electric Power Vehicles
E85	Ethanol Fueled Vehicles
CNG	Compressed Natural Gas Fueled Vehicles
LNG	Liquefied Natural Gas Fueled Vehicles
HYD	Hydrogen Power Vehicles (i.e. Fuel Cells)
PHEV	Plug-in Hybrid Vehicles

The PVM relies on EMFAC2014 output to serve as baseline input data. Specifically, the EMFAC2014 model was run to generate outputs on vehicle population, VMT, daily trips, fuel consumption and emissions, specific to calendar year (2010 to 2050) and model year (1966-2050) for each vehicle type, technology, and geographic area combination. While the HDV module maintains the majority of specificity from EMFAC2014, speed bins and hourly data are aggregated.

The EMFAC outputs were aggregated and combined to generate baseline input data such as specific attrition rates, accrual rates, trips rates, emission factors, fuel economies and sales fractions in a format compatible with the PVM. The details on how these EMFAC2014 data were combined or aggregated are briefly discussed below.

Baseline Model Inputs:

The PVM requires inputs for attrition rates, activity, emission factors, fuel economies and sales fractions for all vehicle and technology types. EMFAC2014 only provides output for gasoline, diesel and electric vehicle technologies. In the case of electric vehicle technologies, EMFAC2014 only provides output for LDA and LDT1 vehicle types. As a result, it was necessary to assign values to other vehicle/technology type combinations based on assumptions regarding similarities to the vehicle behaviors and engine technologies found in EMFAC2014.

As an example, Table 1 provides a summary of how the various vehicle/technology types found in EMFAC2014 were assigned to the vehicle/technology types represented in the PVM.

Table 1: EMFAC2014 Vehicle Type and Technology Assignment in the PVM

VISION	VISION	EMFAC 2014 Category Assignment			
Vehicle Type	**Technology Type**	**Accrual/Trip Rate**	**Attrition Rate**	**Fuel/Energy Consumption Factors**	**Pollutant Emission Factors**
LDA	GAS	LDA-GAS	LDA-GAS	LDA-GAS	LDA-GAS
LDA	DSL	LDA-DSL	LDA-DSL	LDA-DSL	LDA-DSL
LDA	ELE	LDA-OTH	LDA-OTH	User Defined	LDA-OTH
LDA	ETH	LDA-GAS	LDA-GAS	User Defined	LDA-GAS
LDA	CNG	LDA-GAS	LDA-GAS	User Defined	LDA-GAS
LDA	LNG	LDA-GAS	LDA-GAS	User Defined	LDA-GAS
LDA	HYD	LDA-OTH	LDA-OTH	User Defined	LDA-OTH
LDA	PHEV	LDA-GAS	LDA-OTH	LDA-GAS/User Defined	LDA-GAS/LDA-OTH
LDT1	GAS	LDT1-GAS	LDT1-GAS	LDT1-GAS	LDT1-GAS
LDT1	DSL	LDT1-DSL	LDT1-DSL	LDT1-DSL	LDT1-DSL
LDT1	ELE	LDT1-OTH	LDT1-OTH	User Defined	LDT1-OTH
LDT1	ETH	LDT1-GAS	LDT1-GAS	User Defined	LDT1-GAS
LDT1	CNG	LDT1-GAS	LDT1-GAS	User Defined	LDT1-GAS
LDT1	LNG	LDT1-GAS	LDT1-GAS	User Defined	LDT1-GAS
LDT1	HYD	LDT1-OTH	LDT1-OTH	User Defined	LDT1-OTH
LDT1	PHEV	LDT1-GAS	LDT1-OTH	LDT1-GAS/User Defined	LDT1-GAS/LDT1-OTH
LDT2	GAS	LDT2-GAS	LDT2-GAS	LDT2-GAS	LDT2-GAS
LDT2	DSL	LDT2-DSL	LDT2-DSL	LDT2-DSL	LDT2-DSL
LDT2	ELE	LDT2-GAS	LDT2-GAS	User Defined	LDT1-OTH
LDT2	ETH	LDT2-GAS	LDT2-GAS	User Defined	LDT2-GAS
LDT2	CNG	LDT2-GAS	LDT2-GAS	User Defined	LDT2-GAS
LDT2	LNG	LDT2-GAS	LDT2-GAS	User Defined	LDT2-GAS
LDT2	HYD	LDT2-GAS	LDT2-GAS	User Defined	LDT1-OTH
LDT2	PHEV	LDT2-GAS	LDT2-GAS	LDT2-GAS/User Defined	LDT2-GAS/LDT1-OTH
MDV	GAS	MDV-GAS	MDV-GAS	MDV-GAS	MDV-GAS
MDV	DSL	MDV-DSL	MDV-DSL	MDV-DSL	MDV-DSL
MDV	ELE	MDV-GAS	MDV-GAS	User Defined	LDT1-OTH
MDV	ETH	MDV-GAS	MDV-GAS	User Defined	MDV-GAS
MDV	CNG	MDV-GAS	MDV-GAS	User Defined	MDV-GAS
MDV	LNG	MDV-GAS	MDV-GAS	User Defined	MDV-GAS
MDV	HYD	MDV-GAS	MDV-GAS	User Defined	LDT1-OTH
MDV	PHEV	MDV-GAS	MDV-GAS	MDV-GAS/User Defined	MDV-GAS/LDT1-OTH
OBUS	GAS	OBUS-GAS	OBUS-GAS	OBUS-GAS	OBUS-GAS
OBUS	DSL	OBUS-DSL	OBUS-DSL	OBUS-DSL	OBUS-DSL
OBUS	ELE	OBUS-GAS	OBUS-GAS	User Defined	LDT1-OTH
OBUS	ETH	OBUS-GAS	OBUS-GAS	User Defined	OBUS-GAS
OBUS	CNG	OBUS-GAS	OBUS-GAS	User Defined	OBUS-GAS
OBUS	LNG	OBUS-GAS	OBUS-GAS	User Defined	OBUS-GAS
OBUS	HYD	OBUS-GAS	OBUS-GAS	User Defined	LDT1-OTH
OBUS	PHEV	OBUS-GAS	OBUS-GAS	OBUS-GAS/User Defined	OBUS-GAS/LDT1-OTH
UBUS	GAS	UBUS-GAS	UBUS-GAS	UBUS-GAS	UBUS-GAS
UBUS	DSL	UBUS-DSL	UBUS-DSL	UBUS-DSL	UBUS-DSL
UBUS	ELE	UBUS-GAS	UBUS-GAS	User Defined	LDT1-OTH
UBUS	ETH	UBUS-GAS	UBUS-GAS	User Defined	UBUS-GAS
UBUS	CNG	UBUS-GAS	UBUS-GAS	User Defined	UBUS-GAS
UBUS	LNG	UBUS-GAS	UBUS-GAS	User Defined	UBUS-GAS
UBUS	HYD	UBUS-GAS	UBUS-GAS	User Defined	LDT1-OTH
UBUS	PHEV	UBUS-GAS	UBUS-GAS	UBUS-GAS/User Defined	UBUS-GAS/LDT1-OTH
SBUS	GAS	SBUS-GAS	SBUS-GAS	SBUS-GAS	SBUS-GAS
SBUS	DSL	SBUS-DSL	SBUS-DSL	SBUS-DSL	SBUS-DSL
SBUS	ELE	SBUS-GAS	SBUS-GAS	User Defined	LDT1-OTH
SBUS	ETH	SBUS-GAS	SBUS-GAS	User Defined	SBUS-GAS
SBUS	CNG	SBUS-GAS	SBUS-GAS	User Defined	SBUS-GAS
SBUS	LNG	SBUS-GAS	SBUS-GAS	User Defined	SBUS-GAS
SBUS	HYD	SBUS-GAS	SBUS-GAS	User Defined	LDT1-OTH
SBUS	PHEV	SBUS-GAS	SBUS-GAS	SBUS-GAS/User Defined	SBUS-GAS/LDT1-OTH

(1) Baseline Attrition Rates

Attrition rates represent the survival fraction of vehicles of a particular age remaining in a fleet as the fleet ages. The PVM attrition rates are specific to vehicle type, technology type and geographic area. In the case of LDA, LDT1, LDT2, MDV and UBUS vehicle types, attrition rates are the same for all technology types. In the case of SBUS and OBUS vehicle types, attrition rates are different for the various technology types. Survival fractions were derived from EMFAC2014 output using the following equation:

$$\text{Survival Fraction}_{(\text{CY, Age, Type, Tech, Area})} = \frac{\sum \text{Population}_{(\text{CY, Age, Type, Tech, Area})}}{\sum \text{Population}_{(\text{CY-1, Age, Type, Tech, Area})}}$$

(2) Baseline Activity

Activity refers either to the mileage accrual rate for a vehicle (miles/vehicle/day) or the trip rate (trips/vehicle/day). Both of these metrics are used to calculate pollutant emissions or energy consumption when combined with the appropriate emission factor or energy consumption factor. The PVM activity metrics are specific to vehicle type, technology type and geographic area. Activity metrics were derived from EMFAC2014 output for each calendar year and age using the following equations:

$$\text{Daily Accrual Rate}_{(\text{CY, Age, Type, Tech, Area})} = \frac{\sum \text{VMT}_{(\text{CY, Age, Type, Tech, Area})}}{\sum \text{Population}_{(\text{CY, Age, Type, Tech, Area})}}$$

$$\text{Daily Trip Rate}_{(\text{CY, Age, Type, Tech, Area})} = \frac{\sum \text{Trips}_{(\text{CY, Age, Type, Tech, Area})}}{\sum \text{Population}_{(\text{CY, Age, Type, Tech, Area})}}$$

(3) Baseline Emission Factors

Emission factors represent the mass of pollutant emitted per unit of activity. As with attrition rates and activity metrics, the PVM emission factors are specific to vehicle type, technology type and geographic area. Emission factors are further subdivided into various emissions processes depending on the pollutant. In the case of NOx, emission factors are specific to starting exhaust emissions, idling exhaust emissions and running exhaust emissions. In the case of $PM_{2.5}$, there are also emissions associated with brake wear and tire wear. For ROG, evaporative emissions play a significant role, which are further subdivided into running emissions, hot soak emissions, resting emissions and diurnal emissions. Based on practical needs and engineering judgment, several of the processes were combined to create overall emission factors. Table 2 provides a summary of the calculations required to estimate the emission factors for each of the pollutant and process combinations.

Table 2: Baseline Emission Factor Calculations

Pollutant Process Emission Factor	EMFAC2014 Output Calculations	EF Units
NOx Starting (CY, Age, Type, Tech, Area)	∑ NOx Start Emissions (tons/day) / ∑ Trips (trips/day)	tons/trip
NOx Running (CY, Age, Type, Tech, Area)	∑ [(NOx Running Emissions) + (NOx Idle Emissions)] (tons/day) / ∑ VMT (miles/day)	tons/mile
PM2.5 Starting (CY, Age, Type, Tech, Area)	∑ PM2.5 Start Emissions (tons/day) / ∑ Trips (trips/day)	tons/trip
PM2.5 Running (CY, Age, Type, Tech, Area)	∑ [(PM2.5 Running Emissions) + (PM2.5 Idle Emissions)] (tons/day) / ∑ VMT (miles/day)	tons/mile
PM2.5 Brake Wear Emissions (CY, Age, Type, Tech, Area)	∑ PM2.5 Brake Wear Emissions (tons/day) / ∑ VMT (miles/day)	tons/mile
PM2.5 Tire Wear Emissions (CY, Age, Type, Tech, Area)	∑ PM2.5 Tire Wear Emissions (tons/day) / ∑ VMT (miles/day)	tons/mile
ROG Starting (CY, Age, Type, Tech, Area)	∑ ROG Start Emissions (tons/day) / ∑ Trips (trips/day)	tons/trip
ROG Running (CY, Age, Type, Tech, Area)	∑ [(ROG Running Emissions) + (ROG Idle Emissions)] (tons/day) / ∑ VMT (miles/day)	tons/mile
ROG Running Loss (CY, Age, Type, Tech, Area)	∑ [(ROG Hot Soak Emissions) + (ROG Running Loss Emissions)] (tons/day) / ∑ Trips (trips/day)	tons/trip
ROG Resting Loss (CY, Age, Type, Tech, Area)	∑ [(ROG Diurnal Emissions) + (ROG Resting Loss Emissions)] (tons/day) / ∑ Population	tons/vehicle

(4) Baseline Fuel Economies

EMFAC2014 derived fuel economies in the PVM apply to gasoline and diesel technology vehicles only. Table 3 provides a summary of the calculations required to estimate fuel economies for both starting and running operations from EMFAC output. Fuel economies for alternative fuel vehicles are also contained in the PVM and are expressed in units of miles per gasoline gallon equivalent (mpgge). Fuel economies for non-gasoline and non-diesel technologies are not derived from the EMFAC2014 model. They are derived from the National Academy of Sciences study on “Transitions to Alternative Vehicles and Fuels (NRC 2013)” and assigned to the various other technology types found in the PVM.

Table 3: Baseline Fuel Economy Calculations

Fuel Consumption Process	EMFAC2014 Output Calculations	Units
Starting Fuel Consumption	Trips (trips/day) / Fuel Consumption (gallons/day)	trips/gallon
Running Fuel Consumption	VMT (miles/day) / Fuel Consumption (gallons/day)	miles/gallon

(5) Baseline Sales Fractions

The sales fractions for the various technology types found in the PVM are specific to vehicle type, technology type and geographic area. EMFAC2014 only provides sales fractions for gasoline vehicles, diesel vehicles and, in the case of LDA and LDT1 vehicle types, ZEV equivalent vehicles (i.e. electric vehicles, fuel cell vehicles and plug-in hybrids). The sales fractions for a given calendar year were determined based on the number of "Age 0" vehicles in a given calendar year and calculated using the following equation:

$$\text{Sales Fraction}_{(\text{CY, Type, Tech, Area})} = \frac{\sum \text{Population}_{(\text{CY, Age(0), Type, Tech, Area})}}{\sum \text{Population}_{(\text{CY, Type, Tech, Area})}}$$

(6) Additional Modifications to EMFAC2014 Data

Additional modifications were made to EMFAC2014 output to create the final baseline used as the starting point for evaluation of all other Vision scenarios, as listed below.

- *Splitting total ZEV sales between LDA and LDT2 vehicle categories.* EMFAC2014 apportions all ZEV sales resulting from the Advanced Clean Cars regulation to LDAs only. For the VISION baseline, total ZEV sales from the EMFAC2014 model were split between LDA and LDT vehicles. The sales fraction splits begin in 2016 and reflect a greater proportion of ZEV sales being allocated to the LDT2 category. Specifically, 0% of ZEV are allocated to LDT2s in 2015 but gradually increase to 20%, 33% and 25% in 2025 for BEVs, FCEVs, and PHEVs, respectively.

- *Accrual and trip rate reductions to account for the impacts of SB375.* These VMT reduction factors are region specific and are based on SB 375 targets. These adjustments apply to all vehicles in LDA, LDT1, LDT2, MDV categories.

- *Accrual and trip rate reductions to LDA and LDT2 BEVs for model years 2010 to 2025.* These reductions reflect the reduced range of BEVs for these model years relative to gasoline-powered vehicles. Specifically, the accrual rate for an LDA/LDT2 BEV is 50% of an LDA/LDT2 gasoline vehicle for model year 2010. The accrual rate for each successive model year increases gradually until model year 2025 whereby the accrual rate for BEV and gasoline vehicles are equivalent. In order to keep the total VMT constant for the LDA and LDT2 sector, the accrual rates for gasoline vehicles were increased by an adjustment factor each calendar year to account for the reduced BEV VMT. The magnitude of the adjustment factors ranged from 0.0 to 0.3%.

- *eVMT degradation for PHEVs*. The EMFAC2014 model assumes the eVMT fraction of total VMT travelled by PHEVs is constant (i.e. 40%) throughout the life of the vehicle. For the VISION baseline, staff assumed there was degradation in the eVMT fraction of total VMT travelled by PHEVs such that the eVMT fraction decreases over the life of the vehicle. Specifically, the eVMT fraction decreases with age such that the eVMT fraction is only 90% of new vehicle (i.e. age 0) eVMT fraction by the time the vehicle reaches age 15. The Cleaner Fuels and Technology scenario discussed below explores the impact of the expanded eVMT.

- *eStart fraction for PHEVs.* The EMFAC2014 model assumes the eStart fraction (i.e. the number of starts in electric mode) for PHEVs is constant (i.e. 40%). For the VISION baseline, staff assumed the eStart fraction is 20% throughout the life of the vehicle.

- *Increased fuel efficiency in PHEVs.* The fuel efficiency of PHEVs while operating in combustion mode is increased by 25% to account for the advanced design and fuel efficiency of the engines in these vehicle types.

Passenger Vehicle Module Scenario Assessments:

“SIP Measure Concepts” Scenario: This scenario simulates the penetration of more BEVs, FCEVs and PHEVs into the passenger vehicle fleet and the impacts of increased fuel efficiency in gasoline vehicles. It also incorporates the penetration of more SULEV20 vehicles in the fleet. Cleaner urban buses and battery-electric urban buses begin to enter the fleet as well. Specifically, the following assumptions are made:

- Combined LDA/LDT2 “ZEV/PHEV” sales increase from 18% to 40% between 2025 and 2030.
- MDV ZEV/PHEV sales beginning 2026, ramping up to 10% by 2030.
- Increased fuel efficiency (~2.9% per year) between 2025 and 2035 for gasoline vehicles.
- 100% SULEV20 sales by 2030 for gasoline LDAs.
- BEV UBUS sales begin in 2018 and ramp up to 100% sales in 200.
- More stringent NOx standards for new UBUS beginning in 2017 (90% cleaner).

“Cleaner Technologies and Fuels Scenario: This scenario contains all the assumptions in the 'SIP Measures' scenario and extends them out to 2050. VMT and trip rate reductions are also included. Specifically, the following assumptions are made:

- Extension of LDA/LDT2 ZEV/PHEV sales beyond 2030 to 100% by 2050.
- Extension of MDV ZEV/PHEV sales to 50% by 2050.
- Continued fuel efficiency gain (~2.9% per year) between 2035 and 2050 for gasoline vehicles.
- VMT reductions for LDA/LDT/MDV between 2020 and 2050 (15% reduction by 2050).
- Extended electric range for PHEVs after 2025 up to 60% eVMT by 2050.

HEAVY DUTY VEHICLE (HDV) MODULE

The Vision 2.0 Heavy Duty Vehicle (HDV) Module is a scenario planning tool for all on-road diesel and gasoline trucks and vehicles with over 8,500 pounds (lbs) gross vehicle weight rating (GVWR). The exceptions to these weight categories are buses which are generally over 8,500 lbs GVWR but are covered in the Passenger Vehicle Module. All of the baseline information, including vehicle populations, vehicle miles traveled (VMT), age distributions, and emission factors are obtained directly from ARB's EMFAC2014 model. While the HDV module maintains the majority of specificity from EMFAC2014, speed bins and hourly data are aggregated. The HDV Module (and EMFAC2014) groups heavy duty vehicles using the following categories:

EMFAC Vehicle ID	Description
LHD1 - DSL/GAS	Light-Heavy-Duty Trucks (GVWR 8501-10000 lbs)
LHD2 - DSL/GAS	Light-Heavy-Duty Trucks (GVWR 10001-14000 lbs)
T6 Ag - DSL	Medium-Heavy Duty Diesel Agriculture Truck
T6 CAIRP heavy - DSL	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR>26000 lbs
T6 CAIRP small - DSL	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR<=26000 lbs
T6 instate construction heavy - DSL	Medium-Heavy Duty Diesel instate construction Truck with GVWR>26000 lbs
T6 instate construction small - DSL	Medium-Heavy Duty Diesel instate construction Truck with GVWR<=26000 lbs
T6 instate heavy - DSL	Medium-Heavy Duty Diesel instate Truck with GVWR>26000 lbs
T6 instate small l- DSL	Medium-Heavy Duty Diesel instate Truck with GVWR<=26000 lbs
T6 OOS heavy - DSL	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR>26000 lbs
T6 OOS small - DSL	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR<=26000 lbs
T6 Public - DSL	Medium-Heavy Duty Diesel Public Fleet Truck
T6 utility - DSL	Medium-Heavy Duty Diesel Utility Fleet Truck
T6TS - GAS	Medium-Heavy Duty Gasoline Truck
T7 Ag - DSL	Heavy-Heavy Duty Diesel Agriculture Truck
T7 CAIRP - DSL	Heavy-Heavy Duty Diesel CA International Registration Plan Truck
T7 CAIRP construction - DSL	Heavy-Heavy Duty Diesel CA International Registration Plan Construction Truck
T7 NNOOS - DSL	Heavy-Heavy Duty Diesel Non-Neighboring Out-of-state Truck
T7 NOOS - DSL	Heavy-Heavy Duty Diesel Neighboring Out-of-state Truck
T7 other port - DSL	Heavy-Heavy Duty Diesel Drayage Truck at Other Facilities
T7 POAK - DSL	Heavy-Heavy Duty Diesel Drayage Truck in Bay Area
T7 POLA - DSL	Heavy-Heavy Duty Diesel Drayage Truck near South Coast
T7 Public - DSL	Heavy-Heavy Duty Diesel Public Fleet Truck
T7 Single - DSL	Heavy-Heavy Duty Diesel Single Unit Truck

EMFAC Vehicle ID	Description
T7 single construction - DSL	Heavy-Heavy Duty Diesel Single Unit Construction Truck
T7 SWCV - DSL	Heavy-Heavy Duty Diesel Solid Waste Collection Truck
T7 tractor - DSL	Heavy-Heavy Duty Diesel Tractor Truck
T7 tractor construction - DSL	Heavy-Heavy Duty Diesel Tractor Construction Truck
T7 utility - DSL	Heavy-Heavy Duty Diesel Utility Fleet Truck
T7IS - GAS	Heavy-Heavy Duty Gasoline Truck
PTO - DSL	Power Take Off

ARB has released significant data on the EMFAC model data sources, methodology, and output provided (http://www.arb.ca.gov/msei/categories.htm). The following sections mainly discuss the methodology and background of the EMFAC model where it pertains to the scenarios and assumptions used in the Vision 2.0 HDV module. Table 4 outlines the data from EMFAC2014 model that were used in the development of the Vision 2.0 HDV module baseline.

Table 4: EMFAC2014 Data for HDV Module Baseline

Baseline Data Included	Notes
Calendar Year	2010-2050
Season	Annual, Summer, Winter
Region	California county
Vehicle Type	See previous table
Model Year	Engine Model year
Population	The population, VMT, and trips are daily and not annual.
Vehicle Miles Traveled	Daily
Trips	Daily

For each vehicle (as defined by year, season, region, vehicle type, and model year) the emissions and emissions factors associated with different stages of vehicle operation were also imported from EMFAC2014 to form the baseline. The HDV module also aggregates the county level EMFAC2014 outputs into the seven geographic areas, as shown in Figure 2, for the purposes of applying technology.

Baseline Model Inputs:

The HDV Module requires inputs for population, activity, and emissions from all vehicle categories included. From these the module derives attrition, purchasing, emissions factors (by activity measure, or grams per mile). These values are applied to any vehicle category where any non-baseline attrition and purchasing are required (e.g. a new rule requiring turnover), which were not included in the SIP measures but are possible in the model.

(1) Baseline Attrition Rates

Attrition rates represent the survival fraction of vehicles of a particular age remaining in a fleet as the fleet ages. The HDV attrition rates are specific to vehicle type, technology type and geographic area. Survival fractions were derived from EMFAC2014 output using the following equation:

$$\text{Survival Fraction}_{(CY,\ Age,\ Type,\ Tech,\ Area)} = \frac{\sum \text{Population}_{(CY,\ Age,\ Type,\ Tech,\ Area)}}{\sum \text{Population}_{(CY-1,\ Age,\ Type,\ Tech,\ Area)}}$$

These values were averaged over 20 years of age distributions without the impact of the rule to determine the effective baseline attrition rate.

(2) Baseline Activity

Activity refers either to the mileage accrual rate for a vehicle (miles/vehicle/day) or the trip rate (trips/vehicle/day). Both of these metrics are used to calculate pollutant emissions or energy consumption when combined with the appropriate emission factor or energy consumption factor. The HDV activity metrics are specific to vehicle type, technology type, age and geographic area. Activity metrics were derived from EMFAC2014 output for each calendar year and age using the following equations:

$$\text{Daily Accrual Rate}_{(CY,\ Age,\ Type,\ Tech,\ Area)} = \frac{\sum \text{VMT}_{(CY,\ Age,\ Type,\ Tech,\ Area)}}{\sum \text{Population}_{(CY,\ Age,\ Type,\ Tech,\ Area)}}$$

$$\text{Daily Trip Rate}_{(CY,\ Age,\ Type,\ Tech,\ Area)} = \frac{\sum \text{Trips}_{(CY,\ Age,\ Type,\ Tech,\ Area)}}{\sum \text{Population}_{(CY,\ Age,\ Type,\ Tech,\ Area)}}$$

(3) Baseline Emission Factors

Emission factors represent the mass of pollutant emitted per unit of activity. As with attrition rates and activity metrics, the HDV emission factors are specific to vehicle type, technology type and geographic area. Emission factors are further subdivided into various emissions processes depending on the pollutant. In the case of NOx, emission factors are specific to starting exhaust emissions, idling exhaust emissions and running exhaust emissions. In the case of PM2.5, there are also emissions associated with brake wear and tire wear. For ROG, evaporative emissions play a significant role, which are further subdivided into running emissions, hot soak emissions, resting emissions and diurnal emissions. These emissions processes were not combined, but maintained the same level of detail as the EMFAC model.

(4) Baseline Sales Fractions

The sales fractions for the various technology types found in the HDV module are specific to vehicle type, technology type and geographic area. The sales for a given calendar year were determined based on the number of vehicles in the module of a specific model year, compared to the year prior. This was then divided by the total vehicle purchases with a vehicle type and technology to determine sales fraction within a year, as shown in the following equation:

$$\text{Sales Fraction}_{(CY,\ Type,\ Tech,\ Area)} = \frac{\sum \text{Population}_{(CY,\ Age,\ Type,\ Tech,\ Area)} - \sum \text{Population}_{(CY-1,\ Age,\ Type,\ Tech,\ Area)}}{\sum \text{Vehicle Purchases}_{(CY,\ Type,\ Tech,\ Area)}}$$

(5) Baseline/Current Control Programs

The baseline EMFAC data includes a number of ARB and USEPA control measures for trucks, including:

- *GHG Phase I:* US EPAs measure to improve fuel efficiency and reduce green-house gas emissions from heavy duty trucks; reduces GHG emissions by over 20 percent in 2017 from 2000 baseline.
- *ARB Truck and Bus Rule:* ARB's measure to accelerate turnover of heavy duty trucks to the onroad 2010 emission standard by 2023.
- *ARB Drayage Truck Regulation:* Requires drayage trucks in South Coast to upgrade to 2007 or newer engines, with 2010 or newer required in 2023.
- *ARB Public Fleets Rule:* Fleets must apply the Best Available Control Technology (BACT) to reduce PM emissions, with multiple options depending on the truck model year and emissions.

The HDV Module, like the PVM, is designed with capabilities that will allow the user to create scenarios that control a number of variables that impact emissions. Each modification or control can be applied individually to specific vehicle types, by county, by year, and can be introduced as a portion of new sales and imports, or a retrofit, or a mix of the two. The variables that are enabled with this flexibility include:

- Population: Allows direct control of population, increasing or decreasing by a % of total or a discrete number
- Survival: Allows control of population by defining a survival curve
- Purchasing: Both total purchasing and the age distribution of purchased/imported vehicles can be controlled
- VMT: Allows increase or decrease of VMT
- Trips: Trips may be altered independently of VMT
- Emission Control: New technologies/fuels/control strategies are defined by their impact on emissions. Emission factors can be controlled by pollutant by process individually (i.e. a NOx control) or all at once (electrification) or portion thereof.

- Deterioration: Deterioration may be modified (or turned off) independently of emissions control, or in conjunction with controls.

Heavy Duty Vehicle Module Scenario Assessments:

The scenarios included in this version of the HDV module relied on both the baseline data and a series of assumptions about the technologies and implementation, which are documented below. ARB's Mobile Source Strategy document includes descriptions of the measures and the expected benefits, which are not discussed here. Table 5 below provides the technical assumptions that went into modeling the two scenarios in the Strategy document - (1) SIP Measure Concepts; and (2) Cleaner Technologies and Fuels.

Table 5: Technical Assumptions in the Assessed "Strategy" Scenarios

Measure	Assumed in Modeling
Federal Low-NOx Engine Standards	• Flat 90 percent reduction in NOx emissions from 2010 standard, based on possibility of a 0.02 g/bhp-hr standard • NOx from engine deterioration is also reduced by 90 percent in trucks impacted by low NOx standard. Reflects, in part, assumptions on improvements to warranty and engine maintenance. • Full compliance with the rule in the introductory year (no ABT, FLEX credits) at 100 percent of new sales being impacted by the measure
GHG Phase II	• Modeled as a reduction in fuel use and resulting CO_2 without any criteria pollutant benefits • Based on developments from US EPA, modeled as a minor reduction for trailers beginning in 2018 and ramping up to full implementation, with up to 18 percent additional reductions beyond GHG Phase 1.
Last Mile Delivery Electrification	• Applied equally across Class 3-6 trucks, proportional to their populations. • Assumes complete reduction of all pollutants except tire and brake wear

California Low-NOx Engine Standards	• Models local and regional trucks purchased new as being impacted by a California new engine standard, with interstate and/or international trucks not impacted. Migration of used engines into the fleet (used sales) are also assumed to not be impacted by a California standard. The following categories are considered interstate or international.
	    o T6 OOS small
	    o T6 OOS heavy
	    o T7 NNOOS
	    o T7 NOOS
	    o T7 CAIRP
	    o T7 CAIRP construction
	    o T6 CAIRP small
	    o T6 CAIRP heavy
	• Survival rates were derived from multiple years of EMFAC baseline data, and adjusted to remove impact of control programs. Survival rates are specific to technology and truck type but a general example is shown in the graph below.

OFF-ROAD VISION MODULE FOR FORKLIFTS AND AIRPORT GROUND SUPPORT EQUIPMENT

The Vision 2.0 Off-Road Vision module builds off of ARB's official off-road inventories for In-Use Off-Road Equipment and OFFROAD2007[5] which contains the Large Spark-Ignited (LSI) Equipment Regulation[6] categories. The Off-Road module forecasts populations, activity, fuel consumption and pollutant emissions for forklifts and airport ground support equipment (GSE). All forecasts are provided out to calendar year 2050.

Baseline Emissions Inventory Assumptions:

The Off-Road Vision module was developed relying heavily on the methodology and output from ARB's official off-road emissions inventory models: OFFROAD2007 for spark ignition equipment; 2010 In-Use Off-Road Emissions Inventory (2010 In-Use) and associated Off-road Simulation Model (OSM) for diesel equipment. The outputs from these three official off-road models serve as baseline for Off-Road Vision, and include information equipment class, type and rating; fuel type and consumption; activity; vehicle population; model and calendar years, geographic location, and pollutant emissions. The module's inventory assumptions such as turnover, activity, sector growth, regional allocation, etc. are also inherited by the fundamental methodologies behind these models. Detailed information on these models is available at: http://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles .

Off-Road Vision Module Scenario Assessments:

Scenarios in the Off-Road Vision module are evaluated through vehicle sales by model year, technology type, and vehicle type. Specifically, this is accomplished by scaling model year output for vehicle types targeted by the proposed measures. The module adjusts the output from these models by selecting the emissions from vehicles targeted and setting their emissions to zero simulating the replacement of a combustion engine with an electric engine.

The "SIP Measure Concepts" scenario in the Strategy document models deployment of zero emission vehicle technologies into targeted equipment categories such as forklifts and airport ground support equipment.

- Zero Emission Off-Road Forklift Regulation Phase 1: This measure considers electrification of small forklifts (less than 65 horsepower) in the industrial and airport ground support sectors through incentives as well as natural and accelerated turnover. Approximately 73% of forklifts in California were determined to be in medium or large fleets, and it was assumed that 90% of qualifying forklifts (aggregate 67.5%) could reasonably be targeted for electrification by 2035 with the electrification starting in 2028. A linear

[5] Mobile Source Emissions Inventory http://www.arb.ca.gov/msei/categories.htm
[6] Off-road Large Spark Ignition Equipment Regulation, http://www.arb.ca.gov/msprog/offroad/orspark/orspark.htm

penetration of replaced equipment to 2035 was applied to the output data from the three official off-road models mentioned above.

- Zero Emission Airport Ground Support Equipment: This measure considers electrification of certain diesel airport ground support equipment (belt loaders, baggage tugs, and cargo tractors) through incentives and natural turnover. Using the turnover inherent in the official OSM model, all new vehicles of these types will be electric starting in 2023. Natural turnover is allowed to accomplish the replacement of the GSEs, meaning equipment that would have been purchased at the normal rate in the future would simply be electric instead of diesel with no acceleration of purchasing habits.

OCEAN GOING VESSEL (OGV) MODULE

The Vision 2.0 Ocean Going Vessel (OGV) module forecasts energy consumption, activity, and pollutant emissions of commercial vessels that are either at least 10,000 gross tons or 400 feet in length in California waters under various SIP compliance strategies. All forecasts from module are provided out to calendar year 2031.

The OGV module output is specific to two different geographic domains. The first is a statewide domain consisting of the entire coastline. The second is the South Coast Air Basin (SCAB) consisting of the counties and geographic areas defined by California Law as the South Coast Air Basin. These two domains have two different outer boundaries over the ocean that are used in the module. The first zone is within 24 nautical miles of the California coastline that is defined in California law and is also used for regulatory purposes. The second zone is within 100 nautical miles of California's mainland coastline. Figure 3 shows the geographic domains for the OGV emissions.

OGV Module Inputs:

The OGV module relies on the Marine Emissions Model (MEM) version 2-3L that will be released in 2015 for the modules baseline input data. The MEM was run to generate data which was further processed to derive baseline input data in a format compatible with the OGV module. The MEM outputs on activity, fuel use and pollutant emissions were aggregated by operational mode, calendar year, and geographic domain. There are four operational modes that characterize vessel activity: transiting (traveling at open sea), maneuvering (slow speed operations while in a port), hotelling (moored to a dock) and anchorage (moored by anchor).

The OGV module also includes data that are not obtained from the MEM. The fuel amount from the MEM only specifies if residual oil or diesel fuel was used, and does not list electricity usage. Electricity use comes from the at-berth shorepower regulation and the MEM only reduces the fuel used caused by this regulation. So the for the OGV module input "the fuel offset" data was determined and the energy potential of the fuel was used to calculate the amount of electricity that was consumed by the vessels. The OGV module also requires turnover rates of the vessels. The MEM provides a turnover rate based on the vessel type. For the purposes of the OGV module, a weighted average of the turnover was calculated.

Figure 3: Statewide and South Coast Geographic Domains

24 nautical mile boundary *100 nautical mile boundary*

South Coast Boundaries

24 nautical mile boundary *100 nautical mile boundary*

The MEM also does not include, at this time, the Energy Efficiency Design Index (EEDI) that came into effect in 2015. This regulation was passed by the International Maritime Organization and requires that new vessels be more efficient in their design. The requirements are that new vessels are to be 10% more efficient beginning 2015, 20% more efficient beginning 2020, and 30% more efficient beginning 2025. Instead of using these reduction values from the regulation, the module uses reductions that were used in IMO's 2014 Greenhouse Gas study, which concludes that average efficiency improvements are 7.5% less than the required reduction factors.

Ocean Going Vessels Module Scenario Assessments:

At-Berth Regulation Amendments: The "SIP Measure Concepts" scenario in the Strategy document expands the current "At-Berth Regulation" to include some of the following vessel types: auto carriers, bulk cargo, general cargo, roll-on roll-off carriers and tankers. It is limited to the ports that are already offering shorepower. The amendment is assumed to start in 2022 at 10% fleet compliance and increases by 10% until 2032 when the rate becomes 50%. Activity reduction for the aggregated data in the OGV module was calculated using data from the MEM.

To calculate the activity reductions, first number of visits that will be affected by the scenario is found along with the total amount of time that is spent in at-berth operation. From this an average time per visit is found for the affected vessels. Since the regulation allows for 3 to 5 hours of auxiliary engine operation for each affected visit, the average time spent at berth is reduced by 4 hours to find the average auxiliary engine runtime reduction. Then this value is multiplied by the compliance rate and the number of port visits affected to find the total amount of reduced engine runtime. This is then turned into a percentage by comparing it to the total amount of time spent at anchorage. The reductions are listed in the Table 5.

Table 5: At-Berth Amendment Reduction Rates

Compliance Rate (%)	South Coast Reduced Runtime (hr)	South Coast Reduction (%)	Statewide Reduced Runtime (hr)	Statewide Reduction (%)
10%	7,603	2.98%	27,911	3.70%
20%	15,206	5.95%	55,822	7.41%
30%	22,809	8.93%	83,733	11.11%
40%	30,412	11.91%	111,644	14.81%
50%	38,015	14.88%	139,555	18.51%

Tier IV Vessel Standards: The "SIP Measure Concepts" scenario in the Strategy document assumes new main and auxiliary engines will achieve a 70% reduction in NOx starting with calendar year 2025. No reductions to PM were assumed. For this scenario, a reduction is calculated for the NOx emission factor. Under the Tier III regulation, the emission factor for NOx is limited to 3.4 g/kWh for slow speed engines. The Tier IV scenario would introduce a NOx emission factor of 1 g/kWh to new vessels starting 2025. The new factor is 71% lower than the current Tier III emission factor.

ENERGY MODULE (EM)

The Vision 2.0 Energy Module is used to evaluate the liquid fuels, electric power, hydrogen and natural gas required to supply the fuel demands modeled by the vehicle fleet modules (or demand modules) under the different scenarios. Specifically, the Vision 2.0 Energy Module (EM) projects consumption of finished fuels, process fuels and feedstock used to supply the energy needs estimated by the demand modules. Additionally, the Energy Module is designed to calculate the upstream WTT criteria pollutant emissions (i.e. emissions resulting from processes related to producing, refining and delivering the needed fuel) associated with all transportation fuel consumption, and the total WTW GHGs based on the composition of the fuels used in the particular scenario.

The Energy Module first processes data inputs from the "vehicle fleet or demand modules" in the form of fuel demands, blending assumptions, supply capacities, emissions and emission factors. The module then outputs consumed quantities of finished fuels, feedstocks, electricity, and other supplies as well as associated emissions required to meet estimated fuel demands from the vehicle fleet modules.

Data for the module are acquired from a number of different sources. Facility emission rates and well-to-wheel GHG emission rate inputs are obtained from facility reports[7], official statewide emissions inventories[8], and CA GREET v2.0[9]. The California Energy Commission (CEC), the US Energy Information Administration, and ARB's Low Carbon Fuel Standard (LCFS) Program provide data on blending input assumptions. Finally, supply capacities are derived from the CEC Weekly Fuels Watch Report, the Department of Energy's Billion Ton Study, and the LCFS Program.

The Energy Module contains a number of different fuels and blendstocks, including:

Table 6: Energy Module - Fuels and Blendstocks

Demand	Blendstocks
Gasoline	CARBOB, Ethanol, Renewable Gasoline
Diesel	ULSD, Bio-diesel, Renewable diesel
Electricity	Coal, Natural Gas, Nuclear, Hydro, Wind,
Natural gas	Fossil, Landfill, AD Gas
Hydrogen	Reformed Natural Gas, Biomass, Wind,
Jet Fuel	Petroleum, Bio-Jet, Renewable Jet

The module can vary blendstock mixes for the various demands to optimize blends to utilize supplies with low carbon intensity. Supply mix choices can be varied for electricity and hydrogen (i.e. by varying the percent of electricity supplied by coal,

7 Facility Emissions Data available at http://www.arb.ca.gov/ei/disclaim.htm
8 Emissions Inventories available at http://www.arb.ca.gov/aqmis2/aqdselect.php
9 California Greet Model available at http://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm

nuclear, or solar power). Finally, the module allows for global, statewide, and regional boundaries to account for "where" emissions occur.

Key processing steps in the Energy Module's design include:

- Importing and processing input files
- Recursing through resources required by each demand bundle
  - Tabulate expended resources
  - Tabulate direct emissions for each required resource
- Calculating and recursing through products required by exported refined fuels
- Amending imported Tank To Wheel (TTW) emissions to include GHG
- Post-processing and exporting data for reporting/charting

Energy Module Inputs:

The outputs from the "vehicle fleet or demand modules" serve as input to the Energy Module. The demand sector fuel bundles are comprised of the following:

EM Fuel Bundle	Description
GAS	Gasoline
DSL	Diesel
O85	85% Blend Alcohol
NG	Natural Gas (pipeline)
CNG	Compressed Natural Gas
LNG	Liquefied Natural Gas
ELE	Grid Electricity
HYD	Hydrogen
JET	Jet Fuel

Demand module TTW emission outputs also serve as inputs to the Energy Module. Before the Energy Module can utilize the imported files, the demand data must be processed. The demands are converted into energy content based upon the lower heating value (LHV) of the fuel indicated by the base fuel data. To reduce any further conversions, the Energy Module performs all calculations in quadrillion btus (or quads).

Product Blending Inputs:

In addition to the demand sector module's input, the Energy Module also requires blending, supply and emission factor inputs for its processes.

- *Liquid Fuels:* The source the EM uses to inform the blend assumptions is LCFS. Appendix B of LCFS's ISOR[10] contains an illustrative scenario for compliance. This compliance curve is used to calibrate the Current Control Programs (CCP) scenario.

[10] Low Carbon Fuel Standard Regulation - http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs2015.htm

In the 2013 Scoping Plan Update[11], a strategy to extend LCFS was discussed. The SIP Measure Concepts and Clean Technology and Fuels scenarios both use an expanded LCFS target of 18% CI reduction in 2030 as a foundation for blending fuels, and contain the low-NOx, low-PM, low-Carbon Intensity (LNPC) Diesel Fuel Standard. The LNPC Standard will require that California purchased diesel fuel is comprised of 50% blend of renewable diesel by 2030. The Phase 3 California Reformulated Gasoline Regulations (RFG3)[12] provide the maximum oxygenate content for CARFG, which is 10% by volume. The scenarios do not exceed this blend wall. ASTM D975[13] provides a similar blend wall for diesel fuel. This places a maximum blend of biodiesel at 5%. The scenarios do not exceed this 5% blend wall for biodiesel.

- *Electric Power:* The major influence to electric power generation blends is the Renewable Portfolio Standard (RPS). Pursuant to SB1078, SB107, and SB2, the RPS requires investor-owned utilities (IOUs), electric service providers, and community choice aggregators to increase procurement from eligible renewable energy resources to 33% of total procurement by 2020. All scenarios use this standard as a foundation for electric power generation blends. In 2015, the signing of SB350 further expands RPS to increase procurement of renewable energy resources to 50% of the total procurement by 2030 which is used in the Clean Technology and Fuels scenario.

  The Emission Performance Standards[14], pursuant to SB1368, limits long-term investments in baseload generation by the state's utilities to power plants that meet an emissions performance standard (EPS) jointly established by the California Energy Commission and the California Public Utilities Commission. Effectively bans new contracts from coal power generators. The CEC projects[15] coal will phase out in 2027-2028. The San Onofre Nuclear Generation Station (SONGS) was retired in 2013. It is assumed that additional natural gas baseload power generators were used to displace the nuclear power SONGS produced. The Diablo Canyon Power Plant (DCPP) is the only remaining nuclear power generation facility in California. The DCPP’s license expires in the mid-2020s. The CCP scenario assumes that DCPP will be relicensed and will continue to generate its current capacity. The SIP Measure Concepts and Clean Technology and Fuels scenarios assume that DCPP will not be relicensed, and displaces the nuclear power with additional natural gas

[11] First Update to the AB 32 Scoping Plan - http://www.arb.ca.gov/cc/scopingplan/document/updatedscopingplan2013.htm
[12] Phase 3 California Reformulated Gasoline Regulations - http://www.arb.ca.gov/regact/2007/carfg07/carfg07.htm
[13] Standard Specification for Diesel Fuel Oils - http://www.astm.org/Standards/D975.htm
[14] Emission Performance Standard - http://www.energy.ca.gov/emission_standards/index.html
[15] Current expected energy from coal - http://www.energy.ca.gov/renewables/tracking_progress/documents/current_expected_energy_from_coal.pdf

baseload generation. The CEC released an analysis[16] of future effects of climate change on California's generated, and procured, hydropower generation. All scenarios displace hydropower and with natural gas production to make up for reduced hydropower generation.

- *Hydrogen:* SB1505[17] regulates the renewable content of transportation hydrogen. The regulation will require providers of hydrogen to produce 33.3 percent of the hydrogen from eligible renewable energy resources. The EM assumes this percentage will be reached in 2020, when SB1505 is expected to go into effect.

Supply Constraints Inputs:

Only two main fuel pathways are constrained by supply inputs.

- *Petroleum Fuels:* The supply curves placed on petroleum fuels do not actually constrain the usage of fossil fuels. The constraint is used primarily for the purposes of calculating the quantity of finished fuels that will be exported to external markets. It is assumed that the quantity of finished petroleum fuels produced in California in 2012 is indicative of the capacity for California's refiners. The 2012 production data was provided by the CEC, based upon the CEC's Weekly Fuels Watch Report[18].

- *Renewable Natural Gas:* The other major supply constraint provided in the Vision model is on Renewable Natural Gas. An ARB internal analysis provided the technical potential of renewable natural gas. The CCP scenario assumes a negligible amount of renewable natural gas production from landfills and dairy sources. The SIP Measure Concepts and the Clean Technology and Fuels scenarios have a modest increase renewable natural gas produced from dairy and landfill sources.

- *Biofuels:* While there isn't a constraint on California produced biofuels, the model assumptions do not exceed an "equal share" analysis of DOE's US. Billion Ton Study Update[19]. The "equal share" of biofuel feedstocks is approximately 6.5 billion gallons gasoline equivalent.

Emission Factor Inputs:

An ARB internal analysis was performed to calculate California-specific statewide average emission factors for upstream fuel production. Criteria pollutant emission factors were derived from several data sources:

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[16] Potential Changes in Hydropower Production from Global Climage Change in California and the Western United States - http://www.energy.ca.gov/2005publications/CEC-700-2005-010/CEC-700-2005-010.PDF
[17] Environmental & Energy Standards for Hydrogen Production - http://www.arb.ca.gov/msprog/hydprod/hydprod.htm
[18] 2012 Weekly Fuels Watch Report - http://energyalmanac.ca.gov/petroleum/fuels_watch/reports/2012_Weekly_Fuels_Watch_RPT.xls
[19] U.S. Billion Ton Study Update - https://bioenergykdf.net/content/billiontonupdate

- CA-specific facility emissions (CEIDARS[20])
- CA-specific fuel production throughputs/capacities (CEC[21], DOGGR[22], EIA[23], DOE)
- CAGREETv2[24] national averages for fuels not currently produced in CA

For the fuels that are not produced in California, a scalar was applied to reflect the differences between average California refineries in comparison to a national refinery (conventional fuel production). GHG emission factors were derived from ARB's statewide GHG emissions inventory program[25].

[20] District Resources for Emission Inventory - Database References - http://www.arb.ca.gov/ei/drei/maintain/database.htm

[21] 2012 Weekly Fuels Watch Report - http://energyalmanac.ca.gov/petroleum/fuels_watch/reports/2012_Weekly_Fuels_Watch_RPT.xls

[22] Department of Conservation's Division of Oil, Gas, and Geothermal Resources - http://www.conservation.ca.gov/dog

[23] U.S. Energy Information Administration - http://www.eia.gov/

[24] CA-GREET 2.0 Model and Documentation - http://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm

[25] California Greenhouse Gas Emission Inventory Program - http://www.arb.ca.gov/cc/inventory/inventory.htm